Workshop " Biological treatment of biodegradable wastes – Technical aspects"

Jointly co-organised by DG Environment and the JRC. Brussels, 8-10 April 2002.

Organic wastes as a resource for Mediterranean soils

M. Soliva[1] and MT. Felipó[2]
[1] Escola d'Agricultura de Barcelona. Universitat Politecnica de Catalunya. Barcelona. Spain
[2] Soil Science Unit. Universitat de Barcelona. Barcelona. Spain

ABSTRACT

An overview of the main soil characteristics and threats in the Mediterranean Basin are analysed. Low organic matter content is one of the common features of Mediterranean soils.

The re-use of organic wastes through soil system for different land purposes seem to be the best way to maintain or improve organic matter contents in those soils.

An extensive characterisation of different sources of organic waste, before and after composting treatment, from Catalonia (Spain) is presented.

Several suggestions are done in order to incorporate best management practices for waste management and their agricultural reuse in relation with sustainability of as southern European region.

MEDITERRANEAN SOILS AND THE EXTEND OF MAIN THREATS

The soils from the south of Europe have a great diversity. The forming-factors which played the most important role for their development and behaviour are the nature of parent material, climate and topography.

Numerous parent materials of different composition and origin are present, but calcimagnesic materials are the dominant in many areas. The soil forming processes are often linked with migration and accumulation of clay, calcium carbonates or more soluble salts as gypsum.

The climate is characterised by warm to hot dry summers, with high solar radiation and high evaporation rates, and generally rainy winters, often with maximum rainfall in autumn. Frost risk is generally limited to very short periods. The most singular climate characteristics are the low mean annual rainfall and the summer drought. The length and intensity of the dry season is a good indicator of moisture stress, which in turn is reversibly related to the length of the growing season.

The landscape topography is among the most varied in Europe. It is marked by relatively young orogenic systems with high, sharp folded and faulted mountains and hills rising close to the coast. The uplands are highly dissected, complex and partially unstable, with many slopes and shallow rocky soils (Zalidis et al, 2002).

An important percentage of this area is used for agricultural purposes and agricultural activity is usually combined with livestock and forest exploitations. The agro-silvo-pastoral systems are traditionally employed since ancient times. The main crops are olives, grapes, almonds, figs and cereals. With irrigation, dominant crops are fruit trees and vegetables.

The Mediterranean ecosystem is fragile not only for its special climatic conditions and varied topography but also because is intensively affected by many and diverse human activities (Felipó, 1996). Significant soil degradation processes have been recognised in this area (EEA, 2001).

Agricultural soils are vulnerable and have been deteriorated over time by the action of different soil degradation processes. Water erosion is a limiting factor for soil development when slopes are pronounced and no conservation practices in agricultural systems or abandoned agricultural land. Generally, the soil organic matter content is low as a result of ancient and frequent cultivation and use of synthetic fertilisers, which induce also to non-point source pollution. Additionally compaction resulting from the repetitive and cumulative effects of heavy machinery is present in some areas.

Over the last half-century irrigation had been the most important change of agricultural land use. The total coverage of irrigated land increased since 1965 to 1982 by almost 50%, (Sánchez-Díaz, 1993). Water resources in general limit the irrigated areas and irrigation is responsible for salt accumulation in soil. (Szabolcs, 1991). Salinisation may occur also as a result of salt mobilisation during summer by evapotranspiration. Desertification, the final stage of the soil degradation process in dry regions, has also been identified in this area and could extend if the main threats are not controlled.

The extension of the dominant soil threats -erosion, salinisation and organic matter decline- in European Mediterranean region has recently summarised by European Commission (2001a) as follow:

- In more than one third of the total land of the Mediterranean basin, average yearly soil losses exceed 15 tones per hectare (UNEP 2000).
- Soil salinisation is affecting an estimated 1 million hectares in the EU, mainly in the Mediterranean countries and is the major cause of desertification. In Spain 3% of the 3.5 million hectares irrigated land is severely affected, severely reducing its agricultural potential, and another 15% is under serious risk.
- Soil organic matter decline is of particular concern in Mediterranean areas. According to the European Soil Bureau, based on limited data available, nearly 75% of the total area analysed in Southern Europe have a low (3.4%) or very low (1.7%) soil organic matter content. Agronomists consider soils with less than 1.7% organic matter to be in pre-desertification stage.

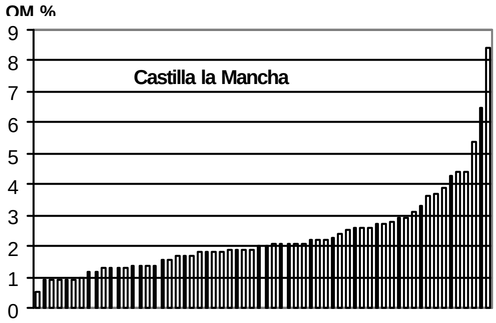
Nevertheless, in southern of European countries there are some differences between soils and their development and/or degradation stages due to intrinsic and extrinsic attributes of soils, both exert a relevant influence on soil process intensity. Soil intrinsic attributes are those given mainly by the forming-factors as nature of parent material, climate severity, landscape topography and natural vegetation. They determine the soil capacity for a specific land uses. The soil extrinsic attributes are subject to change according to the land use and management practices.

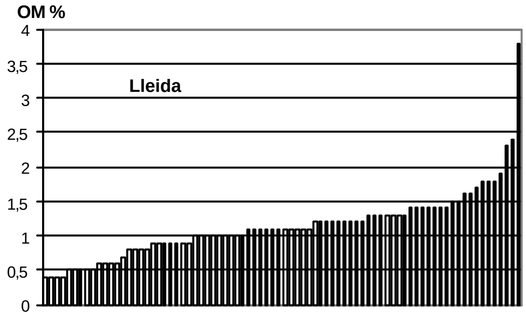
The present low organic matter content in arable soils of Mediterranean region is a result of the ancient cultivation and intensively management over the pas century. In this area the decline in organic matter contents has now become a major process of land degradation (Rusco et al. 2001).

NEEDS OF ORGANIC MATTER FOR MEDITERRANEAN SOILS

It is a fact that the content of soil organic matter in several areas of Mediterranean region is much low than the previous estimated data. Recent regional studies conducted in Spain show the real organic matter content in two areas, Figure 1. One at the central part of the country (Castilla la Mancha) where most of vineyard's soils has less than 1.5%, MAPA 2000a. The other, at the province of Lleida at the north-west of Catalonia, where the organic matter content for the most agricultural soils and pastures is lower than 2% (MAPA 2000b).

Figure1. Organic matter content (%) of agricultural soils in two areas of Spain.





Agricultural soils (vineyards)
- 9 km x km grid
- Total surface: 600 000 ha
- 7386 ha/sample
- Number of samples: 80

MAPA, 2000a

Agricultural soils (cereals, sunflowers, olive, almonds, and fruit threes) and pastures
- Total surface: 554 445 ha
- 8492 ha/sample
- Number of samples: 62

MAPA, 2000b

The relationship between the amount of organic matter and soil properties is well known. The soil properties most likely affected by low organic matter content are the following: Changes in soil structure; Aggravation of crusting; Accelerating of runoff and erosion; Evolving favourable conditions for soil compaction; Increase of soil temperature; Decreasing soil moisture and nutrient retention; Reducing soil fertility, soil biodiversity and biological activity.

The following factors affect the content of organic matter in soils: The climatic conditions, temperature and moisture regimes, which never work separately. The presence of clay minerals in soil what allows forming stable complexes. The kind of agricultural practices and management techniques used, as conservation tillage or non-tillage and crop rotation. The nature of organic material input, the amount of resistant organic matter, being the stability degree a good indicator for waste quality. Notwithstanding, the decomposition of organic matter is relatively constant in a given climate, soil and management system.

Intensive agricultural practices have neglected to maintain soil organic matter content, due to low or no input of plant residues and inappropriate application of farmyard manure. In those conditions the re-use of different organic amendments, in addition to manure, through compost applications seems to be the best way to improving soil organic matter status of such soils (Felipó 1996). For that an accurate management practices should be conducted. Organic wastes (OW) have long been recognised as one of the best methods to maintaining fertility, productivity and soil organic matter. Therefore it can be assumed that OW could be a source of organic matter and a resource for soil protection in Mediterranean basin.

THE OPTION LAND RECYCLING IN ORGANIC WASTE MANAGEMENT

Nowadays there are other reasons for waste re-uses in agricultural soils than to maintaining or improving soil organic matter content. The pressing needs for OW management due to current amount generated. The environmental problems linked with the different waste management options. And the needs to reduce greenhouse gases emission. Those reasons, in general, work always at the same time. While the land application of OW can provide a solution of these needs it does not justify an improper OW management in soils because land reuse could be the worst solution to solve the problems associated with OW management.

To guaranty the capacity of soils to recycle OW it is necessary to control the quantity and the quality of organic matter fraction, the total and available nutrients content for plant and the pollutants content.

It is well known that the background level of nutrients and pollutants is not the same for all soils, waters and crops across the European regions. Consequently the OW re-use for agricultural purposes would impact differently according to their socio-economical, technological and environmental conditions across the European regions. Taking into account the main differences between geographical regions, the OW quality criteria and recommended practices for different land uses must probably be specific for homogeneous areas in the EU.

On the other hand, producers and managers of OW generally accept land spreading as the most economic management option for its management. However when the negative agricultural and environmental impacts previously mentioned are neglected, the full cost of land re-use could be very high for the environment. The Mediterranean region needs an increase in the organic matter content in its soils as well as best management practices for the application OW on soils.

To take the option for OW biological treatment would means also to accept several responsibilities and duties, and change deep-stabilised attitudes.

OW production and its agricultural reuse in Catalonia (Spain)

Currently, two National Programmes for OW management have been established in Spain, one for municipal solid wastes (2000-2006) and another for sewage sludge from urban wastewater treatment plants (2001-2006). The best management practices recommended in both are land recycling. Nowadays, it is still necessary to develop a more accurate information tracking system of waste for production, management and land application.

The farmyard animal manure production is mostly applied to land but in some regions its management results in serious environmental problems. For example, a specific Plan has been developed for pig slurry in Catalonia and 3 thermally dried treatment plants are currently in operation.

Land application of sewage sludge is generally the most common management practices. Biological treatment plants for solid municipal wastes from separate collection streams are currently available in some autonomic communities. For example in Catalonia, region at the NE of Spain, has about 13 operating plants, 1 under construction and 6 are planned.

In Catalonia more than one million hectares, a 35% of the total land, are used for agriculture (ICC, 1997). To stabilise soil organic matter level at present content it is necessary to apply yearly about 350 000 t of organic matter. The crops nutrient requirements are 100 000 t of N, 50 000 t of P_2O_5 and 115 000 t of K_2O (Martínez, 1992).

In 1998, the estimated production of OW in Catalonia was 5 millions t for farmyard manure and 8 millions m^3 for pig slurry. In the year 2000, the estimated amount of fresh matter of sewage sludge applied to soil, directly or after composting, was about 340 000 t, plus 125 000 t of food processing sludge and 75 000 t of others industrial wastes. The actual potential capacity for compost production from organic fraction of municipal wastes is 300 000 t.

Numerous studies have been conducted in Spain in order to determine OW characteristics and the behaviour in soils after its land recycling. A relation of the published articles before 1993 is recollected in Soliva, 1995a.

CHARACTERISATION OF ORGANIC WASTES PRODUCED IN CATALONIA

In the Escola d'Agricultura de Barcelona, the characterisation of OW from different sources– municipal, agri-industrial, vegetable, manure, sewage sludge and so on - generated in Catalonia have been determined since several years ago in order to know their availability for agricultural reuse. The study was conducted with raw and composted samples, using different mixtures and monitoring the composting process. The current analytical methods used (Saña et al., 1989; Soliva, 1993) are indicated in the bottom of Table 1. The characterisation include both agronomic and some pollutant parameters as heavy metal.

Farmyard manure

Several studies have been done in Catalonia to characterise farmyard manure from different types of livestock animals (Vall· llosera et al., 1988; Soliva and Roselló, 1988; Soliva 1995b; Soliva et al., 2000; Paulet and Soliva, 2000), their composition and characteristics are presented in Table 1.

The most stable organic fraction (SD) of farmyard manure is cow manure and pig slurry thermally dried. The former present also highest amount of residual N (non hydrolysable-N/organic N). In pig treated slurry and in poultry manure the high EC values is due to its composition and low moisture content.

In thermally dried pig slurry the total content of P, K and Na is very high, and at the same time has more Zn and Cu. From those results and in order to protect soils its agricultural reuse should be used with caution.

Table 1. Average characteristics and composition of farmyard manure from different types of livestock animals. Analytical methods used are indicated at the bottom of this Table.

Livestock type	**Cow**	**Pig therm. dried**	**Poultry**	**Rabbit**	**Ostrich**
Nº of samples	8	3	8	10	3
pH (1)*	8,65	7,40	6,45	7,56	7,65
EC dS m^{-1} (1)*	5,10	30,68	17,40	4,80	3,20
		%			
Moisture*	65,28	7,02	25,23	56,22	51,37
TOM (3)	55,66	65,36	68,31	81,49	66,38
ROM (4+3)	24,17	28,71	19,44	27,88	21,65
SD (7)	43,43	43,92	28,46	34,21	37,13
org-N (5)	2,42	2,42	2,75	2,29	1,56
C/N ratio	12	14	12	18	21
nH-N (4+5)	1,15	0,84	NM	0,77	0,78
nH-N/org-N (8)	47,72	34,53	NM	33,73	49,89
P (6)	0,86	2,74	0,59	1,18	1,66
K (6)	2,05	4,98	5,21	1,40	0,78
Na (6)	0,64	2,89	0,64	0,41	9,67
Ca (6)	4,11	0,69	5,01	1,95	1,35
Mg (6)	0,58	1,58	1,76	0,78	0,29
Fe (6)	0,57	0,46	0,89	0,19	0,37
		mg kg^{-1}			
NH_4-N (1+2)*	3217	609	9263	NM	564
NO_3-N (1+2)*	449	12	ND	NM	15
		mg kg^{-1}			
Zn (6)	204	1 450	333	1 109	305
Cu (6)	60	738	NM	82	53
Ni (6)	47	24	23	NM	14
Cr (6)	56	14	NM	10	9
Pb (6)	12	13	NM	27	5
Cd (6)	0,36	1,00	2,86	1,50	0,23

NM = not measured

(1) Determination on extract from 1:5 (wet waste/water at W/V ratio).
(2) Soluble NH_4-N and soluble NO_3-N: extracted as (1) and determined by specific ion electrodes.
(3) TOM (total organic matter) determined by ignition at 560º C.
(4) Two successive hydrolysis with H_2SO_4. First 3h in cool with 72% H_2SO_4, then a dilution with water (≈ 0.07N H_2SO_4,) and boiled to reflux for 5h. In the residue both OM and organic-N content are determined according to (3) and (5) procedures. OM content is expressed as ROM (resistant organic matter) and organic-N content as nH-N (non-hydrolysable nitrogen).
(5) First a Kjeldahl digestion and determined by specific ion electrode.
(6) Total nutrients and heavy metals determined by AA after dissolution of dry ash (ignition at 470º C) in 3N HNO_3.
(7) SD (stabilisation degree = ROM x 100/TOM)
(8) Resistant Nitrogen (NinH-N x100/org-N)
(*) Determinations conducted with wet samples.
Except for moisture content, the results are expressed on an oven-dry basis and are the average of duplicate determinations.

Municipal solid wastes (MW)

In MW the quality of the raw organic material from separate collection (SC) is better than in mechanical separation (MS), the quality of raw MW is shown in Table2. The moister content and organic matter, organic N and heavy metal levels is quite different according to the system used for collection MW (Molina, 1997 and Soliva 2001).

Table 2. Average chemical composition and characteristics of several raw municipal organic wastes: Separate collection (SC) and mechanical separation (MS) of municipal wastes (MW) and vegetable wastes (VW).

	SC (MW)	MS (MW)	V W
Nº of samples	10	6	10
pH	5,87	6,10	7,27
CE dS/m^{-1}	2,64	4,12	2,16
	%		
Moisture	78,26	53,97	25,71
TOM	73,84	56,87	65,34
org-N	2,34	1,83	1,39
C/N ratio	16	17	23
	mg kg^{-1}		
P	0,25	NM	0,15
K	2,32	NM	0,55
Ca	2,85	NM	2,65
Mg	0,45	NM	0,68
Na	0,94	NM	0,21
Fe	0,15	0,92	0,34
	mg kg^{-1}		
Zn	28	569	53
Cu	12	156	22
Ni	24	53	33
Cr	38	49	21
Pb	10	190	14
Cd	ND	0,09	0.14

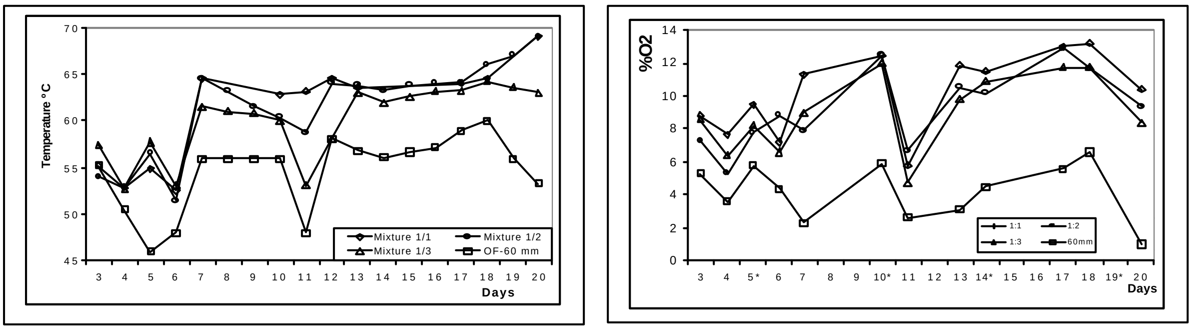
ND = not detected. NM = not measured

In Catalonia, in order to optimise composting treatment for SC and to obtain good quality compost it is necessary to add at least 25-30% by volume of vegetable wastes. This is due to the actual organic fraction characteristics in SC, which has elevated content in several parameters as organic matter and organic-N. At the same time moisture content is also very high. The representative composition of vegetable wastes is as well indicated in the latter column of Table 2.

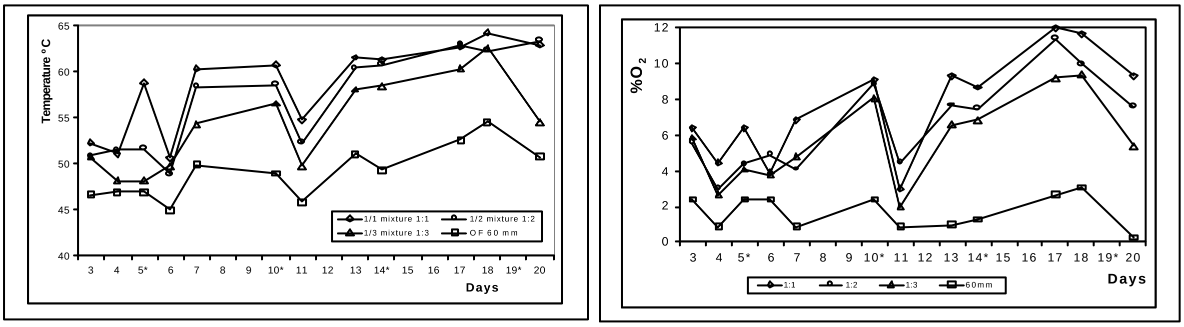
In order to determine the best conditions to optimise composting process, the evolution of control parameters, as temperature and oxygen content, in windrows system was done (Kutter et al., 1985; Nakasaki et al., 1992). For that, measurements were carried out at two depths in mixtures of SC with different amounts of vegetable wastes (Manzano et al, 1998). The results are shown in Figure 2. Temperature and oxygen content improved according to the amount of green wastes added.

Figure 2. Temperature and oxygen levels for the organic fraction of municipal wastes and different ratios of vegetal residues in a windrow composting process.

30 cm



50 cm



Sewage sludge (SS)

Three sample groups are presented in Table 3 for sewage sludge. Analytical results in the first column correspond to samples collected before 1982 in a wastewater treatment plants from small municipalities (Soliva et al, 1982). The second column reflect the actual characteristics of SS and in the third those from thermal dried SS which belong to big municipalities which support also an important industrial activity (Arbiol et al,1993; Paulet and Soliva, 2000).

Table 3. Average chemical composition and characteristics of sewage sludge (SS) compiled in different periods and after specific drying system.

	Old SS	Recent SS	Thermal drying SS
Nº of samples	90	8	5
pH	7,43	7,29	6,22
EC dS m^{-1}	3,87	1,90	1,28
	%		
Moisture	58,60	75,71	5,61
TOM	48,49	62,72	68,78
ROM	17,80	22,40	24,30
SD	36,72	35,71	35,32
org-N	3,55	3,88	4,01
C/N ratio	7	8	9
nH-N	0,68	0,88	0,72
nH-N / org-N	19	23	18
P	1,20	1,93	1,85
K	0,25	0,29	0,25
Na	0,27	0,22	0,24
Ca	7,77	4,71	3,08
Mg	0,43	1,01	0,32
Fe	0,73	1,30	3,56
	mg kg^{-1}		
NH_4-N	NM	9874	552
NO_3-N	NM	5	6
	mg kg^{-1}		
Zn	955	1 264	1 500
Cu	258	291	468
Ni	43	87	136
Cr	162	202	357
Pb	212	155	135
Cd	4	3,24	2

The most important differences between three groups are the P and some heavy metal content, which has increased with time. Fortunately, Pb and Cd content decreased over time. In the other hand, the high Ca content in old SS is due to the treatment process applied in past time, several physico-chemical treated SS are included in that group. This fact is also reflected in less total organic matter content.

Different behaviour in soil for thermal dried SS has to be expected due to the dry treatment and end product shaped presentation as pellets. In this case, waste can not be considered as an organic amendment and slow nutrient release probably occurs in soils.

<u>Other organic wastes</u>

The composition of waste products from diverse industrial sources are presented in Table 4 (Soliva et al, 1983; Huerta and Soliva, 2002). The results express a very heterogeneous composition, there are big differences in organic matter, organic-N, stability degree and nutrients content between waste materials. In general, the heavy metal content is lower than in the former waste group, except for Zn in cosmetic sludge and Cu in textile sludge.

Table 4. Chemical composition and characteristics of several waste products from different industrial sources.

Industrial sources	**Food-processing sludge**	**Paper mill sludge**	**Coffee waste**	**Textile sludge**	**Cosmetic sludge**	**Dairy sludge (A)**	**Dairy sludge (B)**
pH	8,00	7,55	5,66	7,15	11,25	12,10	5,85
EC dS m^{-1}	3,26	0,66	0,98	2,30	3,77	6,99	1,94
			%				
Moisture	85,95	37,89	84,50	50,79	61,47	61,88	80,96
TOM	61,69	31,82	89.44	26,87	49,63	27,06	80.57
ROM	NM	12,19	49,93	5.31	17,39	1.29	12,46
SD	NM	38,30	55,80	19.77	35,04	4,76	15,47
org-N	4,12	0,25	4.45	0,48	1,29	3,04	7,70
C/N ratio	8	65	10	28	17	4	5
P	2,47	0,01	NM	0,37	0,09	0,33	1,53
K	0,46	0,05	NM	0,05	0,03	0,05	0,11
Ca	9,44	18,37	0.10	14	8,77	18,20	2,92
Mg	ND	0,55	NM	0,28	0,21	0,34	0,17
Na	0,46	0,08	NM	0,52	0,57	0,13	0,70
Fe	4,54	0,14	NM	20,9	15,51	2,02	0,36
			mg kg^{-1}				
Zn	521	683	118	357	1 396	151	454
Cu	166	110	32	450	42	20	26
Ni	59	6	18	89	15	29	14
Cr	47	14	24	137	53	39	28
Pb	15	16	18	61	18	4	10
Cd	0,20	0,30	0,1	<1	<1	<1	<1

NM = not measured

The different composition showed for dairy sludge, two latter columns -A and B- in table 4, is attributed to the specific treatment process applied in each dairy industry.

When the quality of waste materials is worse than the organic fraction from separate collection, it is reflected too in the quality of compost mixtures. Therefore, it is obviously necessary to control the quality of the candidate wastes before their addition to the composting process.

<u>Compost</u>

The compost could have a very different characteristic usually due to the nature of incoming raw materials and to the specific conditions of the process.

The average composition of raw vegetable residues (VW) most widely used in MW composting was indicated in the latter column of Table 2. Representative characteristics of compost from two different VW are presented in Table 5. In general the composition of the compostable WV mixtures is adequate for composting, but in greenhouse horticultural wastes plastics are usually included and the resulting compost has high heavy metal content (Paulet and Soliva, 2000). In this case, a separate collection in source should be recommended before its incorporation to composting.

Table 5. Chemical composition and characteristics of compost from different vegetable residues.

	Garden wastes	Greenhouse horticultural wastes
Nº of samples	4	1
pH	7,85	8,90
EC dS m^{-1}	0,98	15,98
	%	
Moisture	54,46	31,41
TOM	47,68	45,66
ROM	28,84	14,75
SD	60,47	32,31
Org-N	1,11	1,64
C/N ratio	22	14
nH-N	0,78	0,97
nH-N/Org-N	70,39	58,88
P	0,28	1,07
K	0,66	0,25
Ca	5,59	10,60
Mg	0,86	1,08
Na	0,21	0,21
Fe	1,06	0,90
	mg kg^{-1}	
NH_4-N	ND	1 259
NO_3-N	15	9
	mg kg^{-1}	
Zn	101	1 459
Cu	66	97
Ni	89	36
Cr	45	76
Pb	39	52
Cd	0,1	5,14

ND = not detected

The average composition of compost from different sources -MW and SS- is presented in Table 6 and compost obtained after mechanical separation from diverse municipalities in Table 7. Comparing composts from Table 7 the traditional agronomic parameter, organic-N content, P and K, only slightly differences between them can be detected. Nevertheless, taking into account other characteristics the differences are greater, it occurs for SD, resistant-N, EC and heavy metal content. SD and N content are greater in separate collection MW and in SS, EC lower in the same materials, and the heavy metal content it is much lower when municipal wastes are collected separately (Molina, 1997; Soliva et al., 2000; Huerta and Soliva, 2002).

Those results mean not only a best quality of input materials but also a better composting development process. Nowadays, the composting plans which treat SC usually works at higher quality levels than those using MS municipal wastes. The quality is reflected in better stability degree and N conservation.

Table 6. Average chemical composition and characteristics of compost from separate collection (SC) and mechanical separation (MS) of municipal wastes (MW), and sewage sludge (SS).

	MW (SC)	MW (MS)	SS
Nº of Samples	79	32	16
pH	8,01	7,56	7,61
EC dS m^{-1}	6,55	9,13	5,52
	%		
Moisture	26,99	27,17	29,57
TOM	53,36	54,23	56,82
ROM	25,23	18,28	26,74
SD	47,70	36,08	49,14
org-N	2,21	1,76	2,33
C/N ratio	12	16	13
nH-N	1,27	0,75	1,08
nH-N/Org-N	56,99	43,06	50,45
P	0,85	0,56	1,97
K	1,35	0,72	0,84
Ca	7,35	7,37	7,27
Mg	0,79	1,13	0,96
Na	0,68	0,33	0,40
Fe	1,01	0,79	1,46
	mg kg^{-1}		
NH4-N	941	1 738,30	2 689
NO3-N	153	53	35
	mg kg^{-1}		
Zn	191	696	646
Cu	83	270	266
Ni	57	101	78
Cr	41	113	114
Pb	65	181	76
Cd	0,38	1,56	0,85

Management practices in composting plants affect compost composition from MS; the most affected parameters are TOM, organic-N and heavy metals. The compost composition depends mainly on the intensity of selection practised in treatment plants (Soliva et al, 1992 and 1993). As a management example the selection practised in plants indicated in Table 7 is explained. In Vilafranca, the higher organic matter content was a consequence of not removing paper and cardboard in composting plant. While, in Mataró the selection practised was so intensive that the composting material was very wet and compacted, with a low C/N ratio. Those conditions affected adversely the composting process and induce to losses in N. In Gavàhe heavy metal content are much higher due to the nature of input raw material which come from a industrialised area in the cincture of Barcelona.

Table 7. Composition and characteristics (mean values) of samples, collected from 1984 to 1991, of municipal wastes from mechanical separation (MS) from three municipalities in Barcelona province.

	Mataró	**Gavà**	**Vilafranca**
Nº of samples	85	42	82
pH	6,8	7,1	7,2
CE dS/m^{-1}	7,2	8,6	7,6
		%	
Moisture	43,4	39,8	44,7
TOM	46,2	57,0	67,7
ROM	13,4	18,6	16,7
SD	29,0	32,6	25,9
org-N	1,15	1,65	1,48
C/N ratio	21	18	22
nH-N	0,38	0,71	0,49
nH-N/Org-N	33	43	33
P	0,38	0,71	0,49
K	0,33	0,43	0,33
Ca	3,53	5,45	5,03
Mg	0,33	0,51	0,37
Na	0,64	0,61	0,77
Fe	0,75	0,98	0,64
		mg kg^{-1}	
NH_4-N	1222	312	443
		mg kg^{-1}	
Zn	608	965	522
Cu	482	734	225
Ni	81	93	51
Cr	135	112	82
Pb	440	810	761
Cd	3	6	5

The heavy metal content in SC from MW composts indicated in Tables 6 does not exceed the values fixed for class 1 in 2^{on} draft working document on "Biological treatment of biowaste" prepared by the European Commission, 2002b. In annex III of this document, the pollutants content is normalised to an organic matter content of 30%. Nevertheless, the SC compost has greater values than this for TOM. By other hand, as previously was stated, Mediterranean soils needs organic matter. For those reasons, there is not sense to force OW composting to obtain a 30% of organic matter content when further land reuse is the recommended option in South European countries. This condition should be obligatory for wastes which destination is landfill disposal. The heavy metal content in other composts indicated in Table 6 and Table 7, as MS from MW and sewage sludge, is greater. In those cases, compost does not comply with the environmental quality classes 1 or 2, proposed in previous indicated 2º draft.

The highest heavy metal content in most wastes is in general Zn. It is probably due both to the generalised use of galvanised materials and the Zn multiple source release in the region.

Currently an interesting experiment on community compost is carried on in several parks in Barcelona town with the participation of the citizens, the average compost composition is indicated in Table 8 (Paulet and Soliva, 2000). In this situation OW suffer a long composting process, which reduce greatly the TOM content. Comparing those results with SC from Table 6, also lower content in N, P and heavy metals is detected. It is probably due to a higher input of garden wastes and vegetable wastes from food products.

Table 8. Community compost from different collecting points (number of samples = 8) in Barcelona public parks.

	Mean	**Range**
pH	8,31	7,62-8,94
EC dS m^{-1}	3,11	1,45-5,24
	%	
Moisture	50,43	39-60
TOM	32,61	21,75-50,55
ROM	17,59	10,64-31,64
SD	54,37	42,62-68,03
org-N	1,40	0,84-2,34
C/N ratio	12	9-18
nH-N	0,76	0,49-1,15
nH-N/org-N	56,99	41,61-72,44
P	0,34	0,18-0,66
K	1,85	1,13-3,13
Ca	7,17	3,59-13,11
Mg	0,58	0,46-0,68
Na	0,25	0,17-0,37
Fe	1,31	0,81-1,9
	mg kg^{-1}	
NH_4-N	ND	ND
NO_3-N	784	27-1 801
	mg kg^{-1}	
Zn	142	85-205
Cu	45	24-64
Ni	25	13-34
Cr	79,	42-110
Pb	37	14-68
Cd	0,33	0,1-0,6

ND = not detected

Most kind of composts have elevated EC, mainly in MS municipal wastes (Table 7). In order to determine the ionic species involved, water extracts with compost from MW were prepared, samples from Germany other than from Spain were included in the experiment (de la Rosa et al, 2000). The results are shown in table 9. Except in NO_3^-, PO_4^{3-} and K^+ samples from Spain have more content in the rest of ionic species than samples from Germany, it is probably due to the soil and water specific characteristics in each geographical region.

When ionic balance is done samples from Mataró and Vilafranca present a lover content in sulphates. Those can be explained because during certain short periods anaerobic conditions were detected in both plants, as previously was commented. In those conditions sulphates had been reduced to sulphides.

Table 9. Chemical composition of MW compost water extracts (1/20) from different countries. The characterisation of samples from Spain is shown in Table 7.

	Spain			Germany
Municipality	*Mataró*	*Gavà*	*Vilafranca*	
Nº of samples	32	12	34	4
pH	7.10	7.25	7.09	7.91
EC dS m^{-1}	3.80	3.60	4.24	1.36
		meq l^{-1}		
HCO_3^-	19.87	29.99	21.58	4.36
Cl^-	12.76	10.14	14.86	3.91
NO_3^-	0.24	0.51	0.22	0.83
SO_4^{2-}	9.37	23.71	11.01	0.74
PO_4^{3-}	0.09	0.06	0.09	0.40
Total anions	42.68	65.36	49.26	10.24
		meq l^{-1}		
Ca^{2+}	32.67	32.37	32.87	2.82
Mg^{2+}	5.80	4.76	5.67	0.40
Na^+	16.93	11.98	17.63	5.25
K^+	7.57	5.45	8.22	6.58
Total cations	62.97	54.50	64.54	15.05

ORGANIC WASTES AS A SOIL AMENDMENT AND AS A SOURCE OF PLANT NUTRIENTS

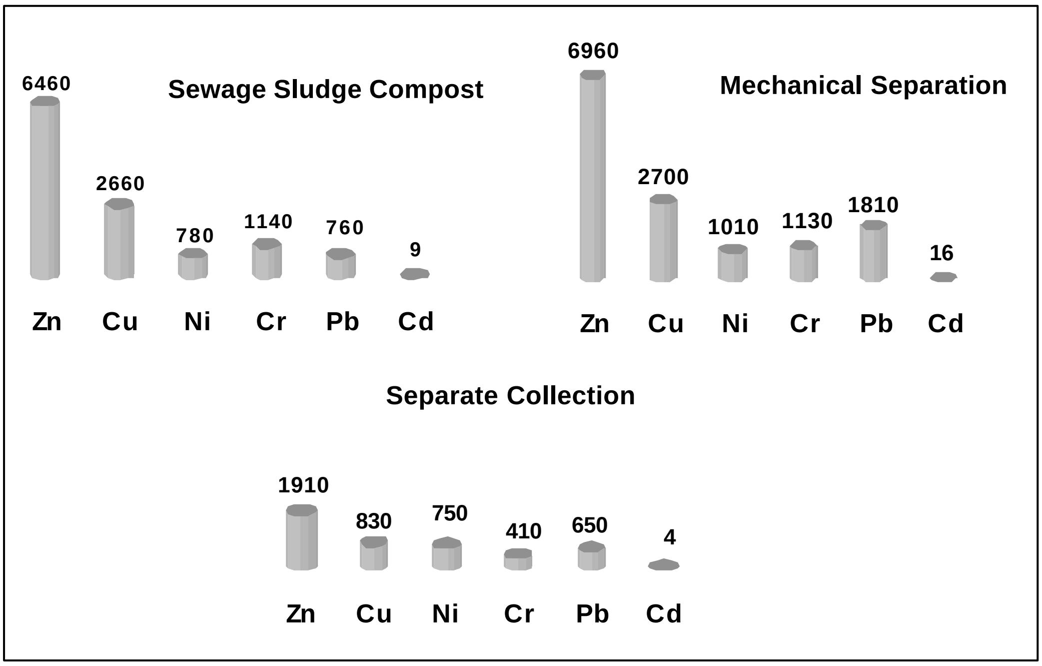
From the previous results it is possible to make the following assertions: In general, excluding animal manure and other similar OW, the best quality materials for land application correspond to the compost of municipal wastes from SC, followed by compost from MS and the worse is municipal sewage sludge. The industrial waste composition and its quality are variable according to the source.

Finally, data presented in Table 10 and Figure 3 can be considered as an exercise to evaluate the differences between the load of several agronomic and pollutant parameters associated to OW soil reuse. For the same rate of dry matter added a similar TOM is applied to soil, but the ROM load added is completely different, and this has an important relevance to maintain organic matter levels in Mediterranean soils. Minimum differences are observed in plant nutrient load added, but to prevent possible long-term environmental impact by excess of N or P it is necessary to control them. Concerning to heavy metals (Figure 3), a great load would be added to soil by applying the same amount of dry matter in SS and MS wastes.

Table 10. Organic matter and nutrients load added to soil resulting from the application of a dose of 10 t ha^{-1} (dry matter) of compost from different raw materials -MW and SS- which chemical composition are previous indicated on table 6.

	MW (SC)	MW (MS)	SS
		%	
Wet matter	13 696	13 730	14 198
Dry matter	**10 000**	**10 000**	**10 000**
TOM	5 336	5 423	5 682
ROM	2 523	1 828	2 674
Org-N	221	176	233
Min-N	9	17	27
P	85	66	197
K	135	72	84

Figure 3. Heavy metal load added to soil resulting from the application of a dose of 10 t ha^{-1} (dry matter) of compost from different raw materials -MW and SS- which chemical composition are previous indicated on table 6.



In order to protect soil quality, OW land recycling cannot be practised only according to the crop fertiliser requirements, other OW quality parameters have to be considered. To achieve this waste selection process based on its composition and properties is necessary to determine whether treatment needs prior to land spreading. Only an accurate assessment of waste quality could maintain long-term good agricultural soil conditions. From an environmental and economical point of view, the best fertilisation practices in this case would be a combination of mineral and organic fertilisation.

FINAL COMMENTS AND CONCLUSIONS

To consider organic wastes as a resource for Mediterranean soils it is first necessary to have the most appropriate answer for several related agri-environmental questions. The following questions have to be considered as an exercise in order to preserve and protect the long-term good conditions of soils and environment.

- Is it necessary to incorporate some filters for raw materials destined for composting treatment?
- Which kind of parameters would be the most adequate to monitoring and control the composting process, the end products and the application sites?
- Which parameters have to be considered in criteria for compost quality?
- Is it necessary to consider the compost quality related to the raw material quality?
- Is it appropriate to include quality classes in compost criteria for different land uses and for different European agricultural regions?
- Is it necessary to introduce Good Management Practices for the treatment plants, improving compost quality and reducing environmental impacts?
- Is it reasonable to introduce Good Farming Practices for land re-use to prevent or reduce negative agricultural and environmental impacts?

In conclusion, to guaranty an accurate OW management through the soil-plant system and to protect agricultural soils and environment it is necessary to consider the following aspects:

- To establish a regulation which consider the mentioned aspects.
- To ascertain the quantity and the quality of wastes generated in a specific area.
- To understand the available treatment and/or management options in order to assess their advantages and disadvantages
- To establish guidelines for land re-use.
- To set up Integral Management Plans at local or regional levels, which include disposal options other than soil recycling.

ACKNOWLEDGEMENTS

The results presented were supported in part by several projects from the Diputació de Barcelona (Catalonia, Spain) and Escola d'Agricultura de Barcelona (ESAB) and by the Spanish Education Ministry, contract numbers AMB92-0577 and AGF96-0966. The authors wish to express their appreciation to M. Alcolea Belloso, O. Huerta Pujol and M. López Martínez for their help in analytical determination and significant contribution.

REFERENCES

- ARBIOL, M., BENITO, P., SOLIVA, M., VILLALVA, D., MOLINA, N.,1993 *Pruning residues and sewage sludge co-composting.* In "Proceedings International Conference on Environmental Pollution" : 677-684.
- de la ROSA J.A., CENTELLES E., ECHEVARRIA S., PAULET S., SOLIVA M., 2000. *Utilització del extracte aquós de mostres de compost per a la seva caracterització*. Congres ICEA. Acts book IV: 321-327
- EEA. 2001. *Down to eart: Soil degradation and sustainable development in Europe. A challenge for the 21st century.* EEA& UNEP, (Copenhaguen: European Environmental Agency, 2000. http//www.eea.eu.int (28/11/01).
- European Commission 2001a. *The Soil Protection Communication* – DG ENV. 2001. Draft 26 October 2001. http://www.europa.eu.int/comm/environment/agriculture/studies.htm (5/12/01).
- EUROPEAN COMMISSION, 2001b. *2on draf Working document on Biological treatment of biowastes.* http://www.europa.eu.int/comm/environment/waste/report11.htm (20/02/02)
- FELIPÓ, MT., 1996. *Compost as a source of organic matter in Mediterranean soils.* In "The Science of Composting", Part I: 402- 412. Eds M de Bertoldi et al,. Blackie Academic Editorial.

- HUERTA, O., SOLIVA, M., 2002. *Data Base on Organic Wastes*. ESAB & Servei del Medi Ambient de la Diputació de Barcelona.
- ICC (1997) *Mapa de classificació dels usos del sòl 1997*-Landsat-TM, Generalitat de Catalunya-DMA. http://www.gencat.es/mediamb/sig/fusos97.htm (20/12/2001).
- KUTTER,GA., HOITINK, AJ., ROSSMAN, LA., 1985. *Effects of aeration and temperature on composting of municipal sludge in a full-scale vessel system*. J. Water Poll. Cont Fed 57: 309-314.
- MANZANO, S., PEREZ, C., SOLIVA, M., 1998**.** *Compostaje conjunto de la fracción orgánica de residuos municipales y residuos vegetales: influencia sobre la temperatura y los niveles de oxígeno.* Residuos 41: 60-67.
- MOLINA, N., 1997. *Informe sobre la qualitat del compost produit a la planta de Torrelles de Llobregat.* Final informs Project ESAB & Junta de Residus del Departament de Medi Ambient GC.
- MAPA, 2000a. *Estudio de los niveles de metales pesados en las parcelas de viñedos de la Comunidad de Castilla-La Mancha*. Ministerio de Agricultura Pesca y Alimentacion (MAPA), Junta de comunidades de Castilla-La Mancha & Laboratorio de Análisis y Fertilidad de Suelos (LAF). Noviembre 2000. Madrid.
- MAPA, 2000b. *Estudio de los niveles de metales pesados en los suelos de la provincia de Lleida.* Ministerio de Agricultura Pesca y Alimentacion (MAPA) & Laboratorio de Análisis y Fertilidad de Suelos (LAF). Diciembre 2000. Madrid.
- MARTINEZ, X., 1995. *Posibles usos de los residuos urbanos en agricultura: abono, enmienda organica y sustrato de cultivo.* In "Gestión y Utilización de Residuos Urbanos para la Agricultura". Edits Fundació "la Caixa" & Aedos. 181 pp.
- NAKASAKI, N., WATANABE, A., KUBOTA, H., 1992 *Effects of oxygen concentration on composting organics*. Biocycle, June: 52-54
- PAULET, S., SOLIVA, M., 2000. *Qualitat del compost de fracció orgànica de residus municipals fabricat a Cataluny.* Final informs Project ESAB & Servei del Medi Ambient de la Diputació de Barcelona.
- RUSCO, E., JONES, R., BIBOGLIO, G., 2001. *Organic matter of the soils in Europe: present status and future trends.* European Soil Bureau. Soil and Waste Unit. Institute for Environment and Sustainability. JRC. Ispra. 12pp.
- SÁNCHEZ-DÍAZ, J., 1993*. Soil-use changes in the Mediterranean Basin and its relation to chemical time bomb.* In "Chemical Time Bomb. Delayed effects to chemicals in Soils and Sediments". Meulen GRB et al (ed). The Foundation for Ecodevelopment. 147-156 pp.
- SAÑA, J., GIRÓ, F., SOLIVA, M., FLORENSA, P., 1989. Methodology used for evaluating the quality of compost produced in Catalonia. In "Simposio Internazionale Produzione el impiego del compost" pp: 343-362 .
- SOLIVA, M., 1993. *Control de la Qualitat del Compost*. In "La gestió municipal dels residus sólids urbans". Ed. Diputación de Barcelona. 129-140 pp
- SOLIVA, M., 1995a. *Presentacion de la Jornadas sobre reutilización de residuos urbanos en agricultura y estado actual del tema.* In "Gestión y Utilización de Residuos Urbanos para la Agricultura". Edits Fundació "la Caixa" & Aedos. 181 pp.
- SOLIVA, M., 1995b. *La aplicación de residuos ganaderos.* In "Zootecnia, bases de producción animal". Co-ordinator C. Buxade. Ed. MundiPrensa. Vol IV: 325-345.
- SOLIVA, M., 2001. *Compostatge i gestió de residus orgànics*. Estudis i Monografies, 21. Ed. Diputació de Barcelona. Servei del Medi Ambient. 111 pp
- SOLIVA, M., FELIPÓ, MT., GARAU, MA., SAÑA, J., 1982. *Com aprofitar per a l'agricultura els fangs residuals derivats de la contaminació*. Ciencia 22: 20-25.
- SOLIVA, M., MOLAS, J., GARCÍA, V., FERRER, R., BALDI, M., 1983*. Possible use residual sludges from paper industry as a substrate.* Acta Hort., 150: 531-544.
- SOLIVA, M., ROSELLÓ, M.J., 1988*. Estudio de los cambios sufridos por residuos de una granja avíciola durante el proceso de transfomación para su uso como abono oergánico*. In "Congreso Internacional de Tecnologias Alternativas": 31-34
- SOLIVA, M., GIRÓ, F., VALERO, J., CUCURULL, D., LUMBRERAS, F., BARBERÀ, R., 1992. *Siete años de estudio de la calidad del compost en Cataluña: criterios para su valoración*. Acts book ISWA. 40pp
- SOLIVA, M., MANZANO, S., GIRÓ,F. 1993. *Nitrogen loss during composting.* Compost Science-Utilization 1(4): 23-26.

- SOLIVA, M., GONZALEZ, C., MOLINA, N., PAULET, S., RODRIGUEZ, N., 2000. *Qualitat del compost de residus municipals generat a Catalunya en plantes de diferents característiques.* In “IV Congres de la ICEA”: 379-385.
- SZABOLCS, I., 1991. Salinization potential of European Soils. In "Land use changes in Europe". Brouwet et al (ed). Kluwer Academic Publishers. NL. UNEP, 2000. *Guidelines for erosion and desertification control management*. United Nations Environment Programme.
- VALL-LLOSERA, X., VOLTAS, J., PUJOLÀ, M., SOLIVA, M., 1988. *Rabbit manure composting.* Acta Horticulturae 302: 279-294
- ZALIDIS, G., STAMATIADIS, S., TAKAVAKOGLOU, V., ESKRIDGE, K., MISOPOLINOS, N., 2002. *Impacts of agricultural practices on soil and water quality in the Mediterranean region and proposed assessment methodology*. Agri, ecosy and environ 88: 137-146.